“International Workshop
On Aging Phenomena in
Gaseous Detectors”
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Aging Studies for the HERA-B Outer Tracker

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(on behalf of the HERA-B OTR Collaboration)

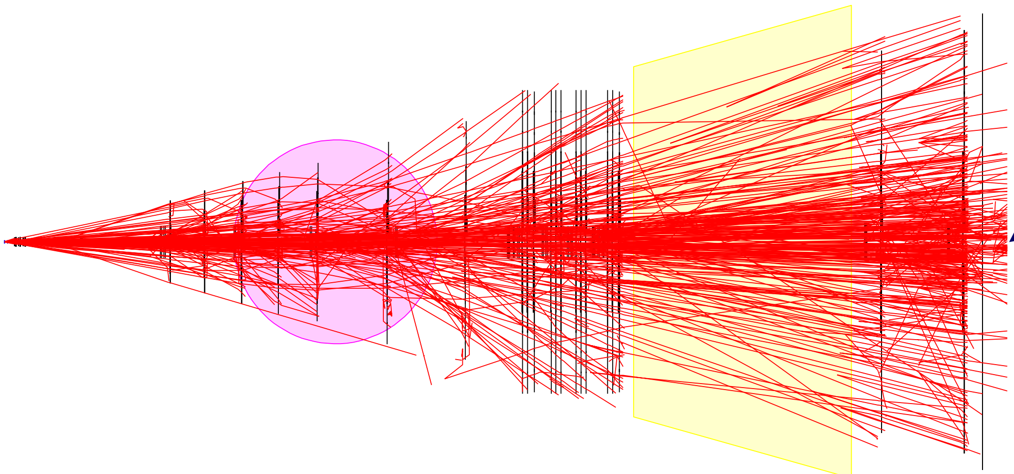
Outline:

1. Design Constraints.
2. Implications for Aging Studies.
3. Mapping the HERA-B Conditions to a Test Beam.
4. Observations and Validation of Building Techniques.
5. Summary.

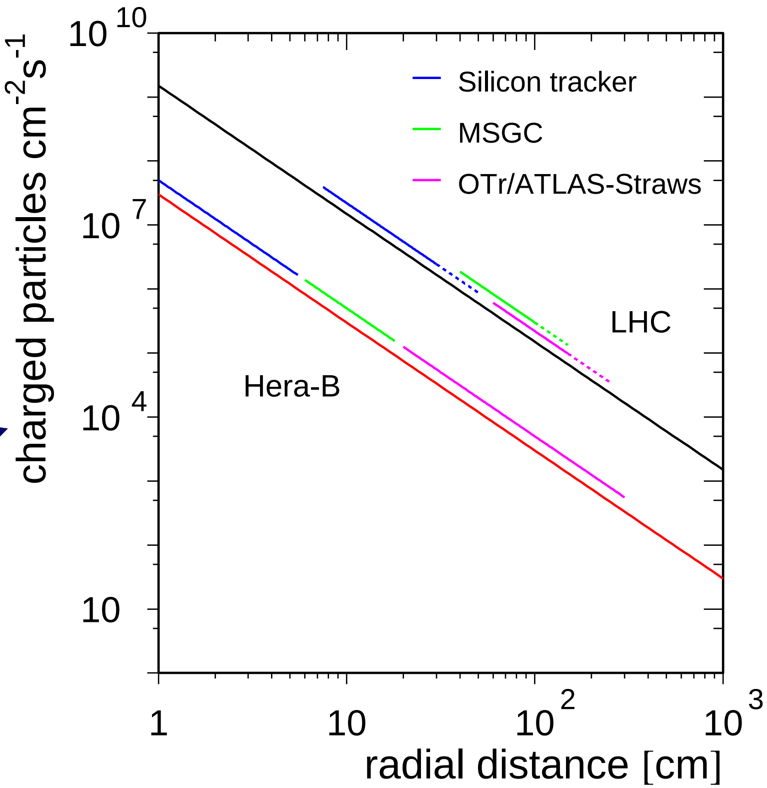
* Now at CERN (EP-Division)

Design Constraints: Particle Flux

4 superimposed p(920 GeV)-N interactions

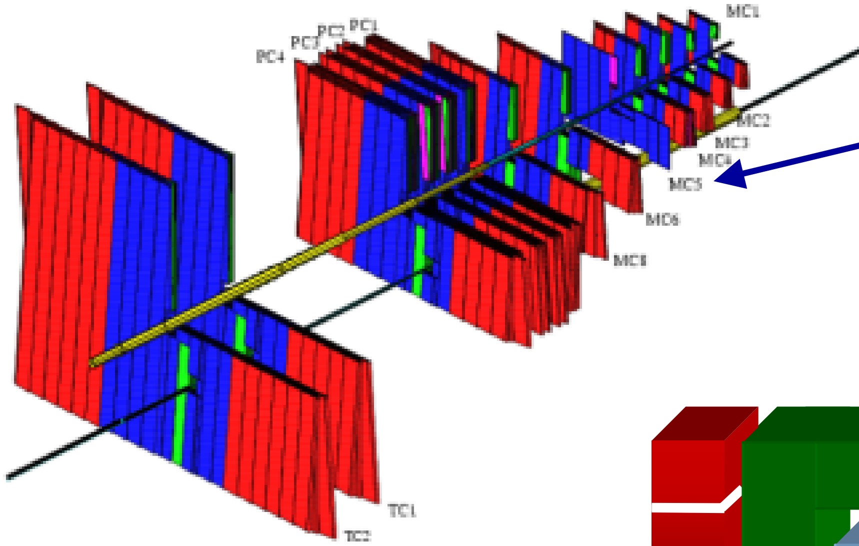


High occupancy in 4 superimposed interactions per bunch crossing every 96 ns



The trackers receive a charged particle flux very similar to some LHC experiments

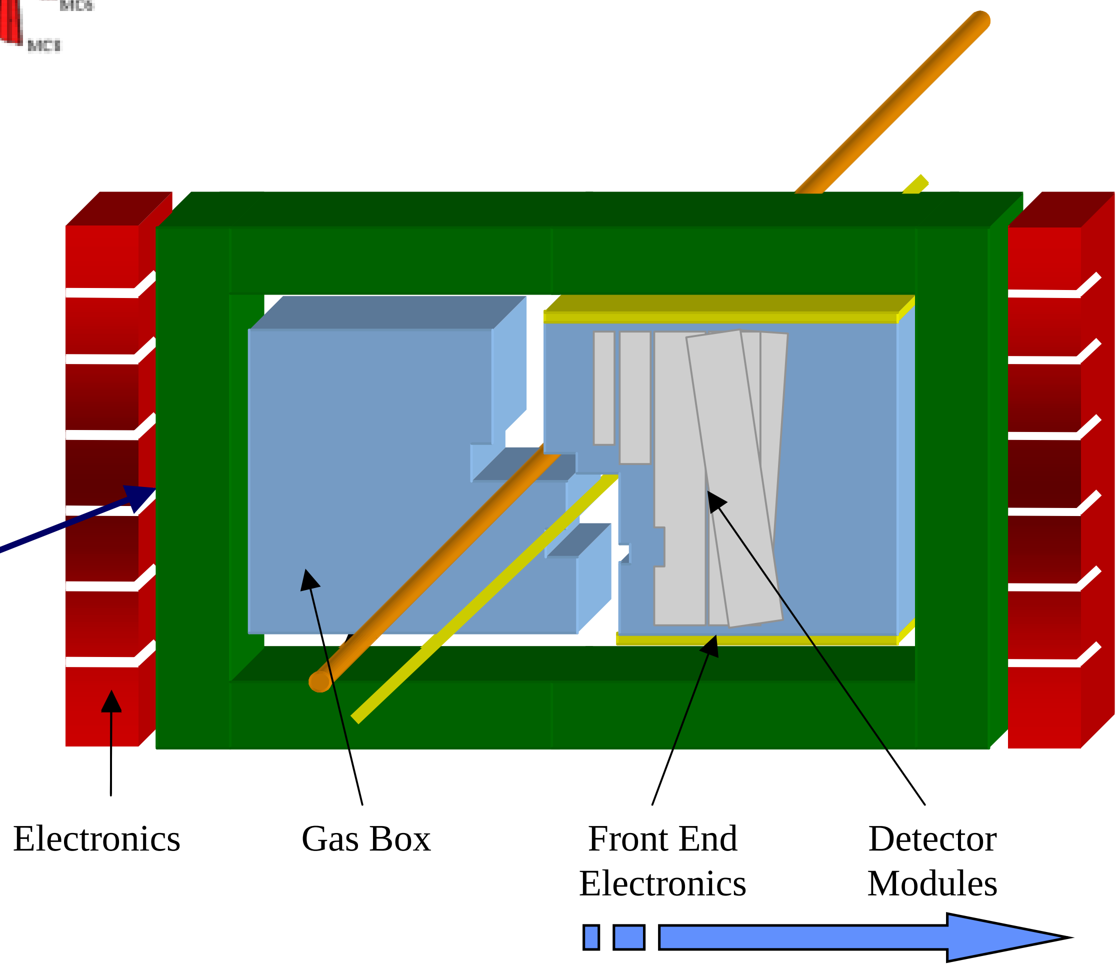
Design Constraints: Size



8 km^2 of cathode surface

20 m^3 of gas exchange/hour

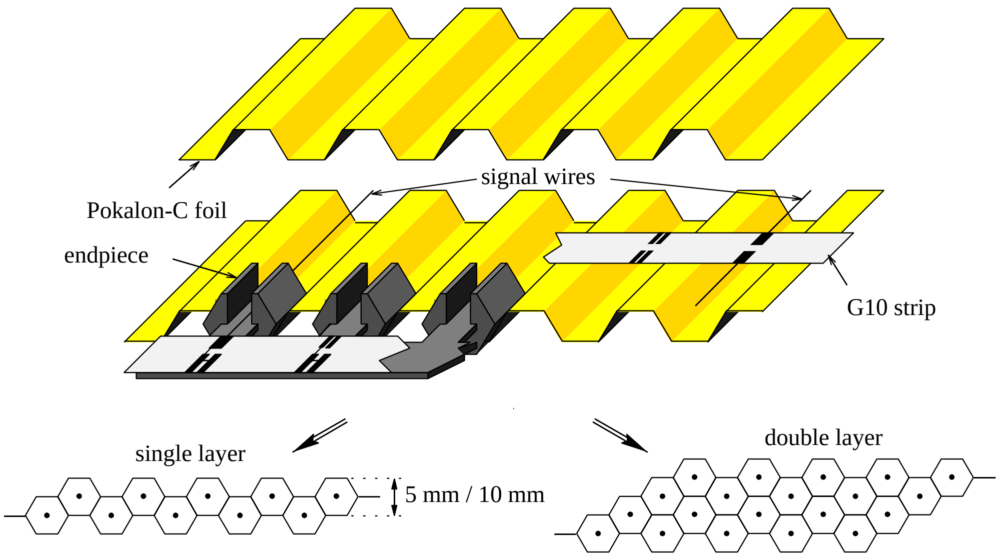
Detector size up to 6.5 x 4.6 m^2



The World Largest Tracker

100 modules with installed in 26 gas boxes

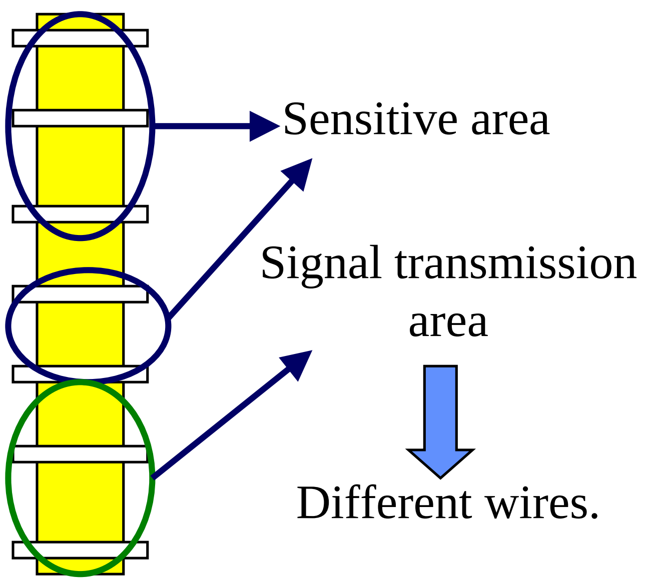
Detector Constraints: Building Technique

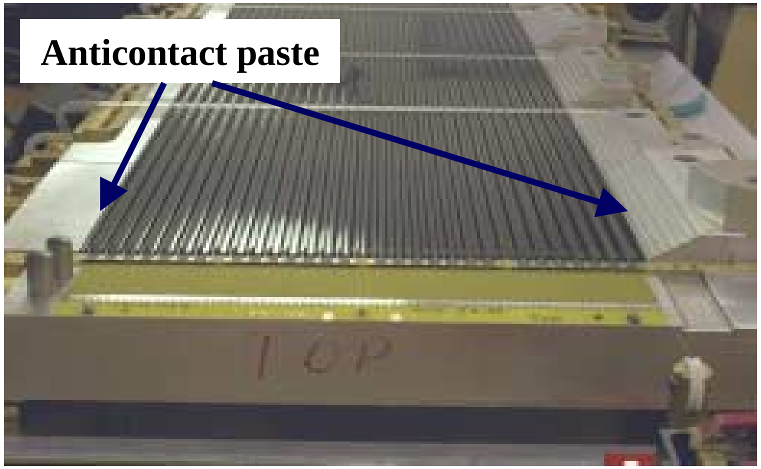


Open geometry
➡ EASY WIRING

Soft structure
in terms of overpressure
➡ External gas volume, so called, GAS BOX

Solder tin and other materials inside the drift cell





Implications for Aging Studies

- Large surface area.
  - Drift distance up to 5 mm.
- Maximum drift time of 96 ns.
- Some chambers inside a magnetic field of up to 0.8 Tesla.

→ Need for a fast (containing CF_4) gas mixture (v_D~100 μm/ns).

Mixtures studied:
- CF_4/CH_4 : 80/20.
- $Ar/CF_4/CH_4$: 74/20/6.
- $Ar/CF_4/CO_2$: 65/30/5.

- Non-closed cell geometry.
  - Gas box in contact with the counting gas.
- Large gas volume.
- Expensive gas (CF_4).

→ Need a re-circulating gas system and special care to all the materials of the gas box.

(look at K. Dehmelt talk and M. Hohlmann poster)

Total Accumulated Charge

- 10 MHz "event" rate.
- Up to 30 % cell occupancy.
- $1/r^2$ particle density dependence.
- Closest point at 20 cm from the beam pipe.
- Attachment in CF_4.
- Electronics noise vs. gain
  - Adjust effective gain to 20k.

Maximum radiation dose/cm/year:

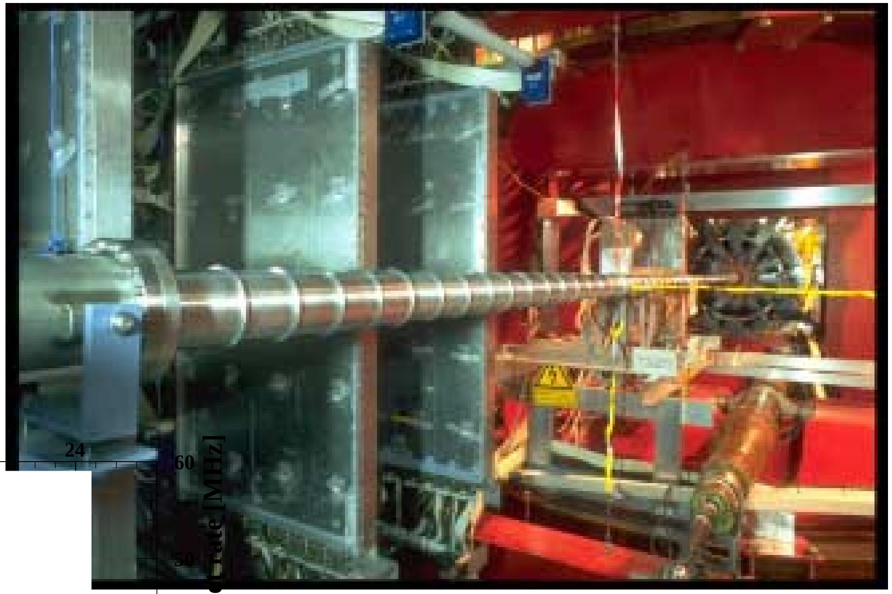
3 MHz particle rate
30-35 primary el./particle
→ 100 fC/particle
10^7 seconds/year.

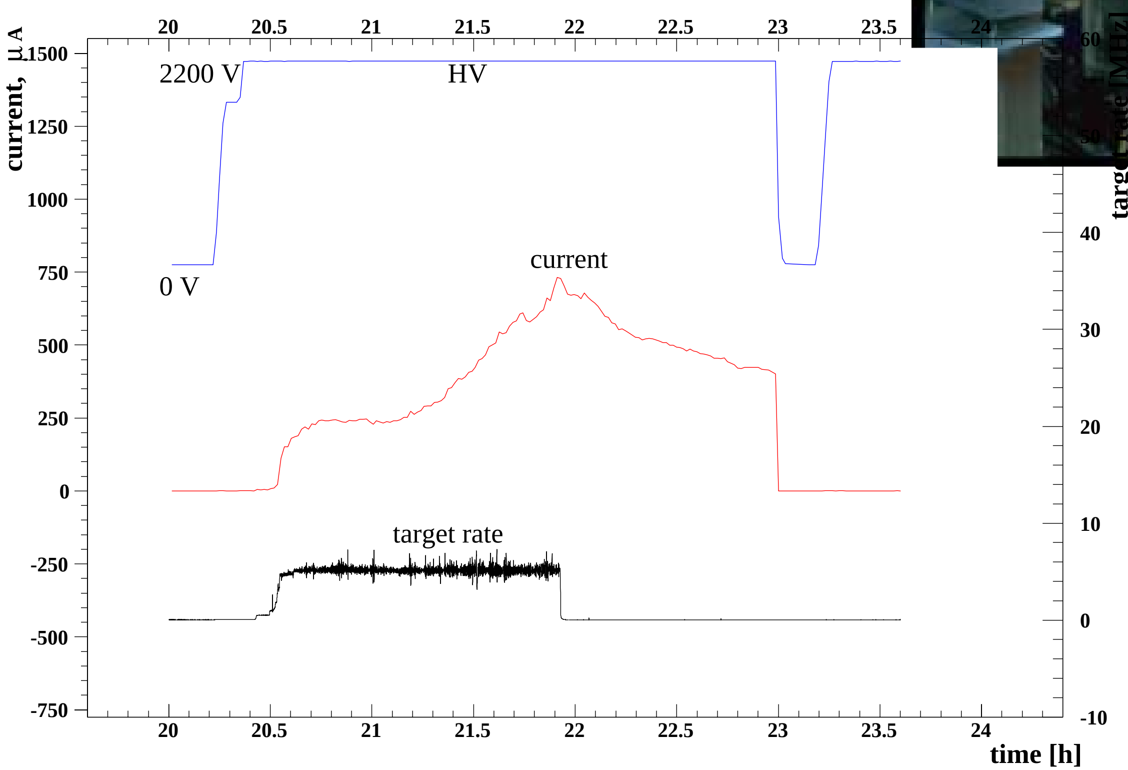
~ 470 mC/cm/year

Detectors must be tested for aging up to 2-3 C/cm.

First Tests in HERA-B

Malter effect in installed modules after ~ 0.5 mC/cm of accumulated radiation dose





Effect observed with gas mixtures containing CH_4

"Similar" effect seen with gas mixtures containing CO_2

Strategy: Two Lines of R&D

- Similar but smaller chambers had shown no aging effects up to 4.5 C/cm of integrated radiation dose in X-rays.
- Other tests in HERA-B showed that adding alcohol to the gas might stop producing Malter effect in the chambers.
  - However, foils are deformed (not viable solution).
- Tests in HERA-B are impractical.

Need R&D to find solutions

- Unclear what triggers the Malter Effect:
  - Irradiation area?
  - Particle type?
  - Irradiation density?
  - Chamber construction?
  - Materials?

Need R&D to find a place where to reproduce the fast appearance of the Malter effect in testable chambers (resemble HERA-B conditions)

Possible Beams: X-rays and Similar

“Effect” stands for fast appearance of Malter effect

Facility Radiation Type	Acc. Charge	Radiation Density	Irradiation area	Gas Mixture	Effect seen?
Zeuthen X-Ray Mo (35 keV)	5 C/cm	1.5 μA/cm	~1x3 cm^2	CF_4/CH_4	NO*
Dubna X-Ray Cu (8 keV)	6 C/cm	5 μA/cm	~0.5x1 cm^2	$Ar/CF_4/CO_2$	NO*
HMI Electron 2.5 MeV	10 mC/cm	0.1-3 μA/cm	~100x 30 cm^2	$Ar/CF_4/CH_4$	NO*
HD X-Ray Cu (8 keV)	~ mC/cm	~0.1 μA/cm	~46x 30 cm^2	$Ar/CF_4/CH_4$	NO*

* Malter effect could be triggered in chambers already irradiated in hadronic beams but that did not showed it there

X-rays cannot trigger the Malter effect independently of their energy or Radiation Density.

Gas mixture does not play a role

Very fast anode aging observed (difficult to see in HERA-B)

Possible Beams: Hadronic Sources

Facility Radiation Type	Acc. Charge	Radiation Density	Irradiation area	Gas Mixture	Effect seen?
Rossendorf Protons 13 MeV/c	5 mC/cm	0.3 μA/cm	~9x9 cm^2	$Ar/CF_4/CH_4$	NO
Rossendorf α-part, 28 MeV/c	3 mC/cm	0.6 μA/cm	~1x3 cm^2	$Ar/CF_4/CH_4$	NO
PSI p 70 MeV/c	~ mC/cm	0.2 μA/cm	~0.5x0.5 cm^2	$Ar/CF_4/CH_4$	NO YES*
PSI π/p 350 MeV/c	~ mC/cm	0.02 μA/cm	~12x22 cm^2	CF_4/CH_4	YES
Karlsruhe α-part, 100 MeV/c	~ mC/cm	0.02 μA/cm	~7x7 cm^2	$Ar/CF_4/CH_4$	YES
HERA-B P(920 GeV)-N	~ mC/cm	0.03 μA/cm	100x30 cm^2	All gas mixures	YES

* Effect could be ignited increasing the irradiation area

A chamber in which the cathode was coated with carbon spray did not show Malter effect

R&D Beam and Open Questions

- Electrons or X-rays do not produce Malter effect.
- Hadrons above certain energy clearly produce Malter effect after few mC/cm (as in HERA-B).
- Charge density seems not to play a decisive role.
- Irradiation area above certain threshold seems necessary.

→

Abeam of α–particles of 100 MeV/c irradiating an area of ~ 30 cm^2 resembles HERA-B conditions

Karlsruhe FZ

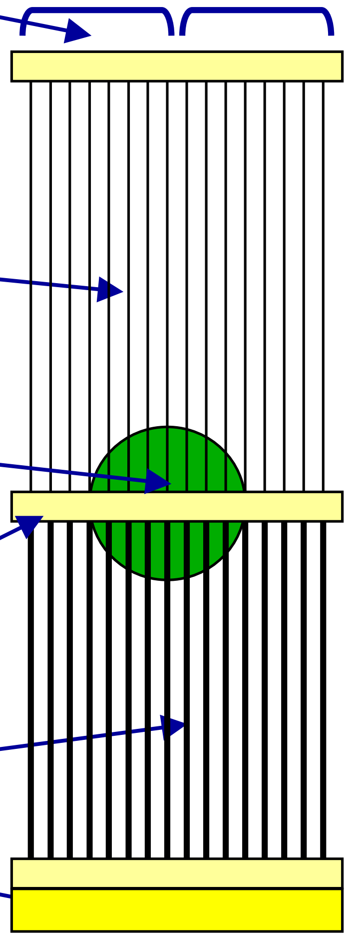
OPEN Questions/To solve:

- Indications that the foil is responsible of Malter effect (coating might help).
- Fast anode aging also needs to be solved.
- All building materials (glues, plastics, wires) and techniques need to be validated.

Karlsruhe Setup: Matrix Diagonalization

Test detector building techniques by varying only one parameter at a time.

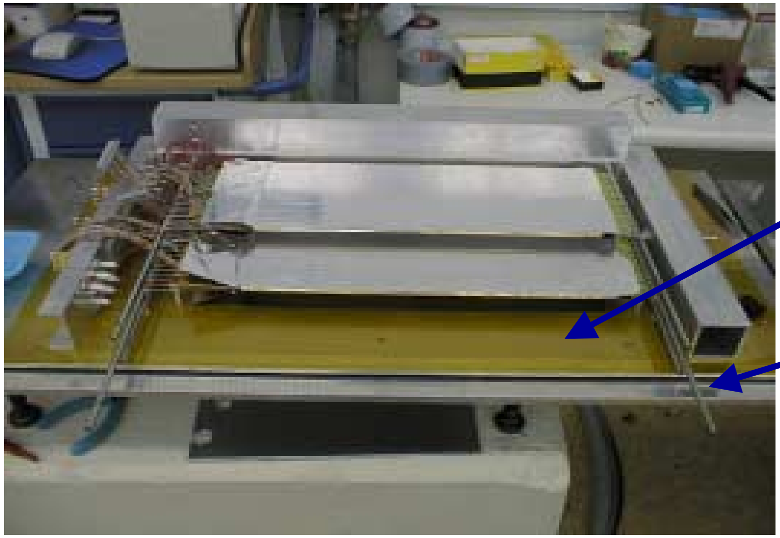
→ Careful test module design.



Tests of:

- Foil Coatings.
- Glues.
- Building Materials.
- Solder tin cleaning.
- Gas flow option.
- Effects of gas contaminants.
- Material cleaning procedures.
- Use of anticontact paste in template.

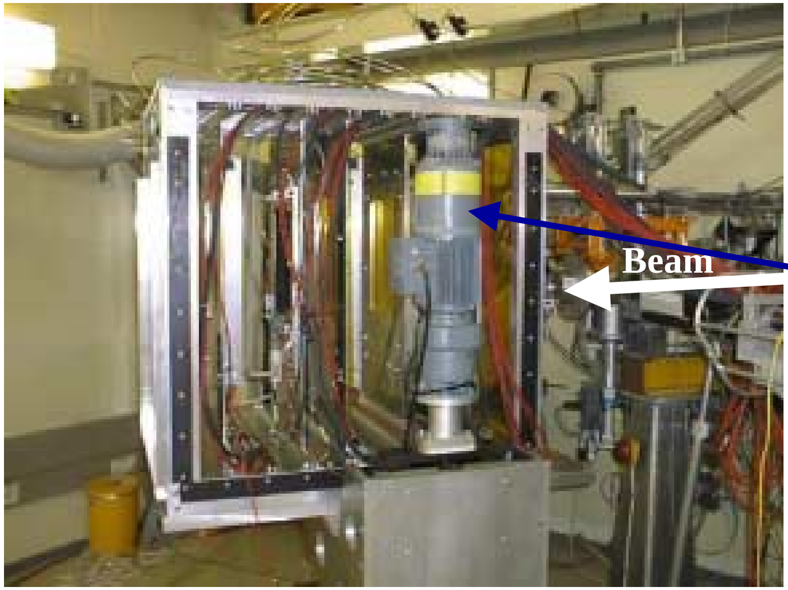
Karlsruhe Setup: Matrix Diagonalization



Kapton and Aluminized Millar for gas box windows

Electro-polished stainless steel gas tubing

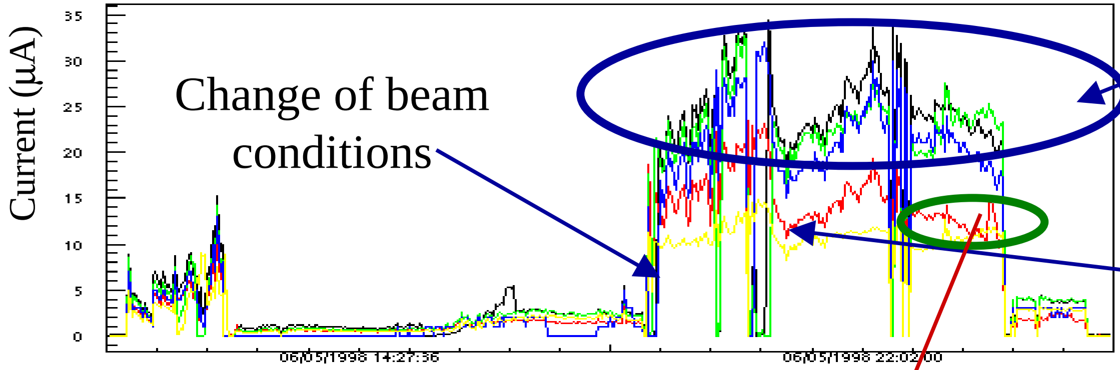
…Lots of modules



Careful positioning of chambers in the beam

…And careful gas monitoring

Fast Anode Aging with $Ar/CF_4/CH_4$

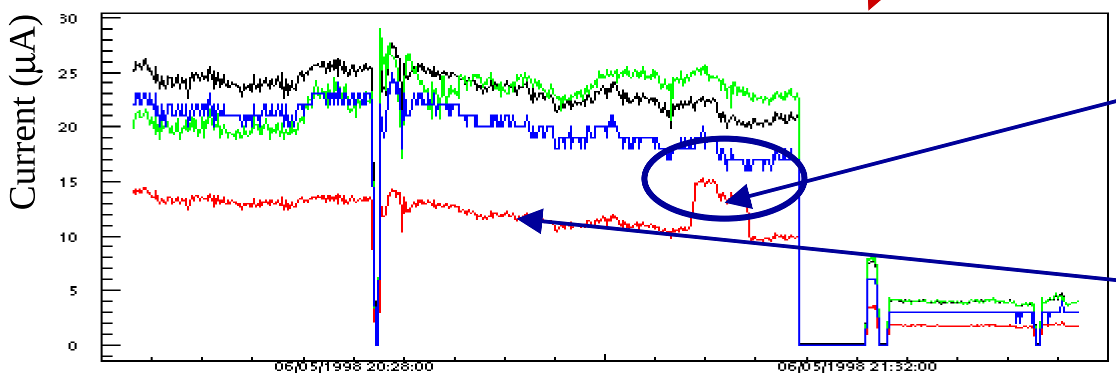


Change of beam conditions

~ 8-10 hours (~ 10 mC/cm)

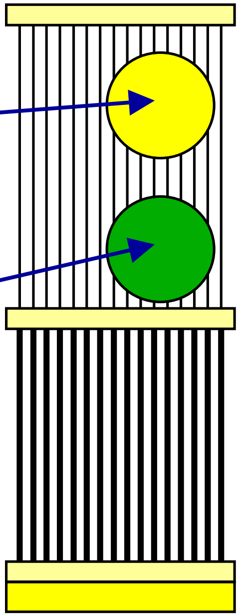
Other chambers. All follow beam fluctuations (different levels correspond to different positions)

Chamber running with $Ar/CF_4/CH_4$ shows relatively less current with larger accumulated radiation dose.



Move beam to a non-irradiated area

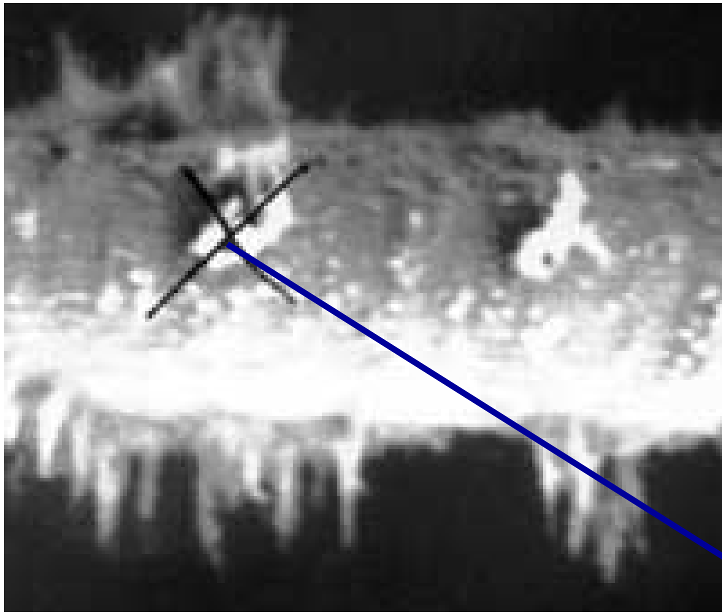
Irradiation area



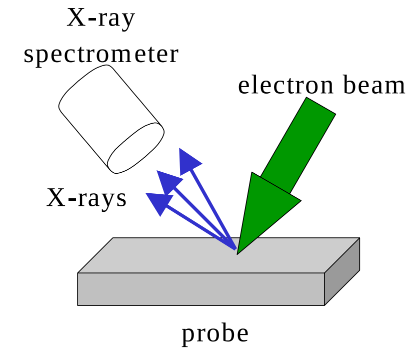
Fast anode aging was observed in all chambers running with $Ar/CF_4/CH_4$ independently on the building technique (glues, …)

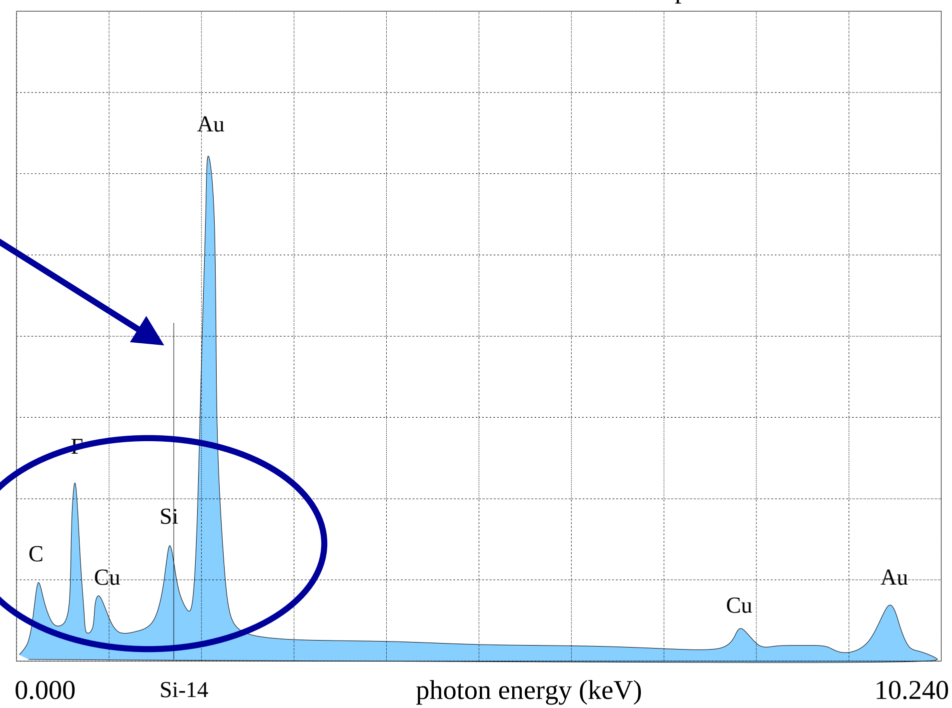
Wire Inspection

Wire from a aged chamber



Result from
Energy
Dispersive X-ray
Spectroscopy

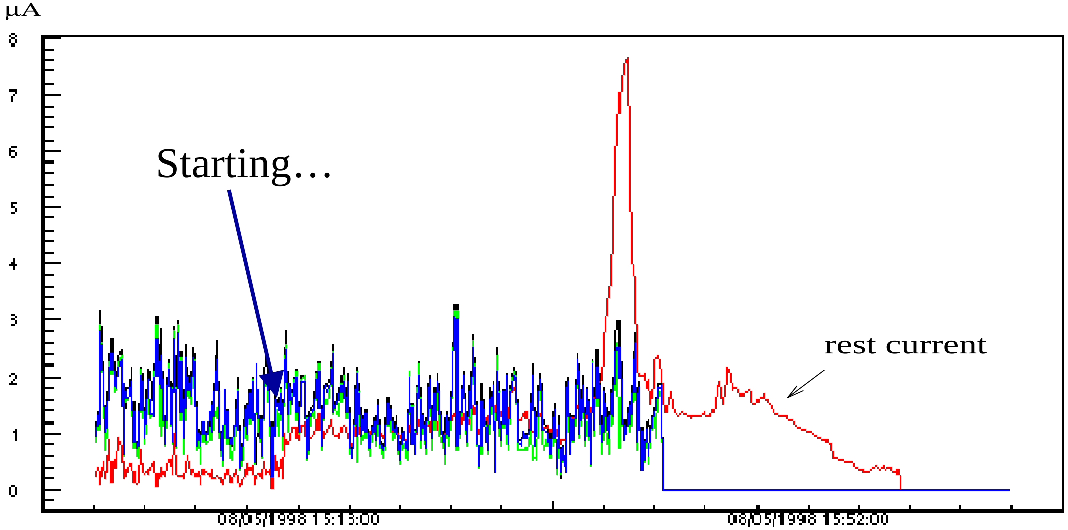




Typical elements coming form the radicals produce in the amplification avalanche

Malter Effect Reproduced

Non-coated Pokalon-C cathode chamber with $Ar/CF_4/CH_4$ gas mixture

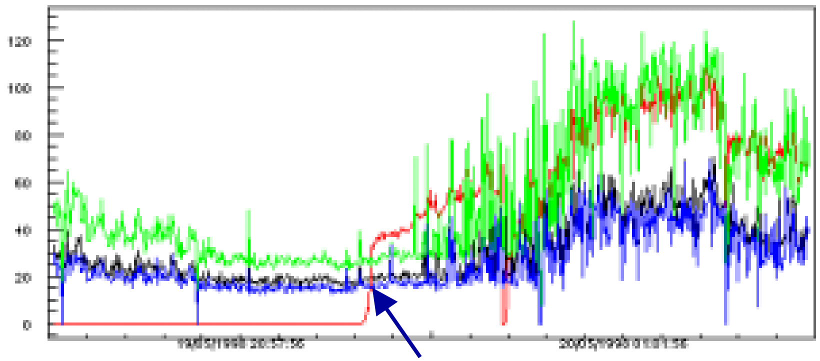


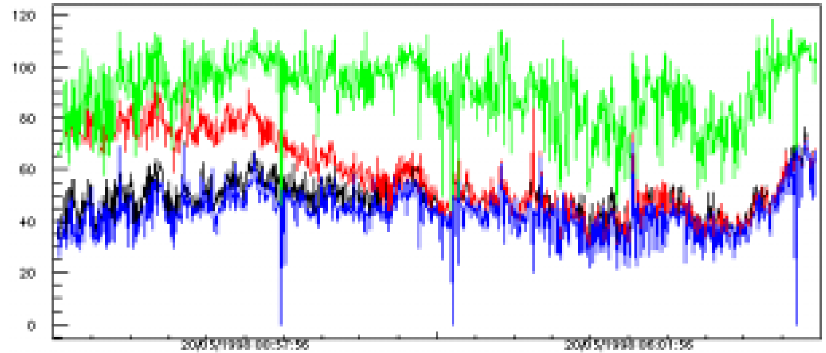
Observation after ~10 mC/cm (and after chamber had shown fast anode aging)

- There might be in interplay between the fast anode aging and the Malter effect phenomena.
- In $Ar/CF_4/CO_2$ gas mixture, spurious rest currents were observed with uncoated Pokalon-C cathode foil, but not so clear Malter Effect.

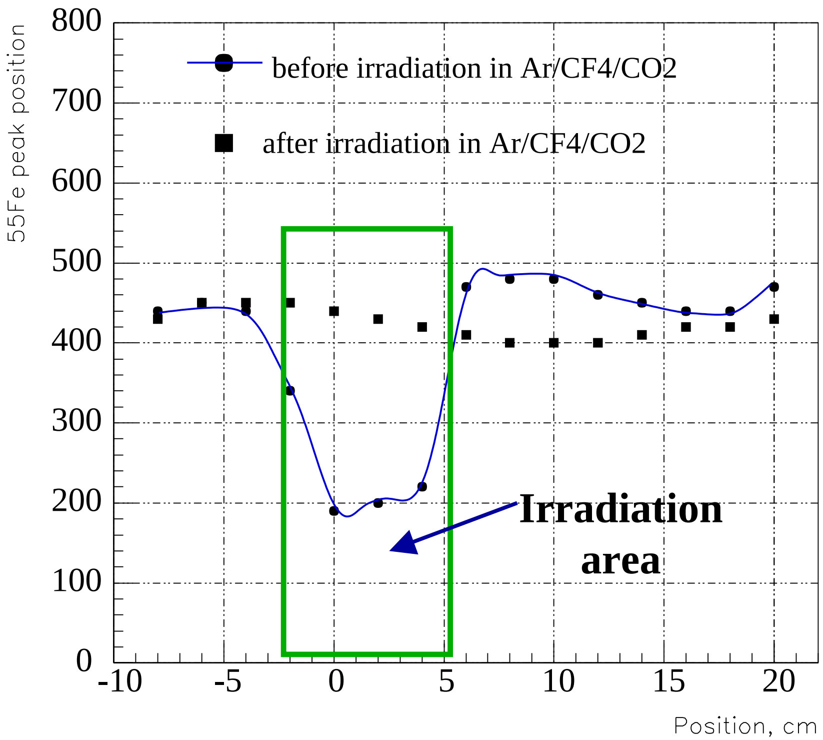
Malter effect was never observed in coated chambers independently of the running gas and building techniques.

Recovery: Exchange $CH_4 - CO_2$





Start irradiation after gas exchange



A chamber previously irradiated with $Ar/CF_4/CH_4$ that showed fast anode aging and Malter effect was completely recovered after several hours of irradiation with $Ar/CF_4/CO_2$

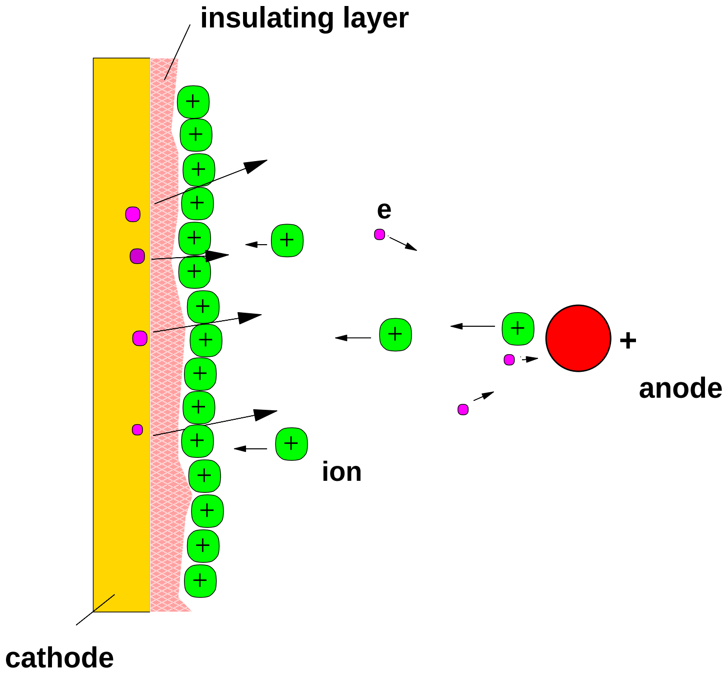
(CF_4 wire and cathode etching??)

Malter Effect in Pokalon-C Chambers

- Electron Microscopy of the aged Pokalon-C foil show that there are some "islands" of non-surface conductivity in the foil. (see G.Bohm poster)
- Three factors are abosulutely needed to create the Malter effect
  - Non-coated Pokalon.
  - Hadronic beam above certain energy.
  - CH_4 in the gas or some impurities (HERA-B).

Formation Mechanism:

- Hadrons produce permanent changes in the foil.
  - Explains "after-triggering"
- The foil develops a non-insulated layer around the non-conductive islands with some gases and/or impurities.
  - Explains "area-effect"
  - Explains "gas-impurities" need.

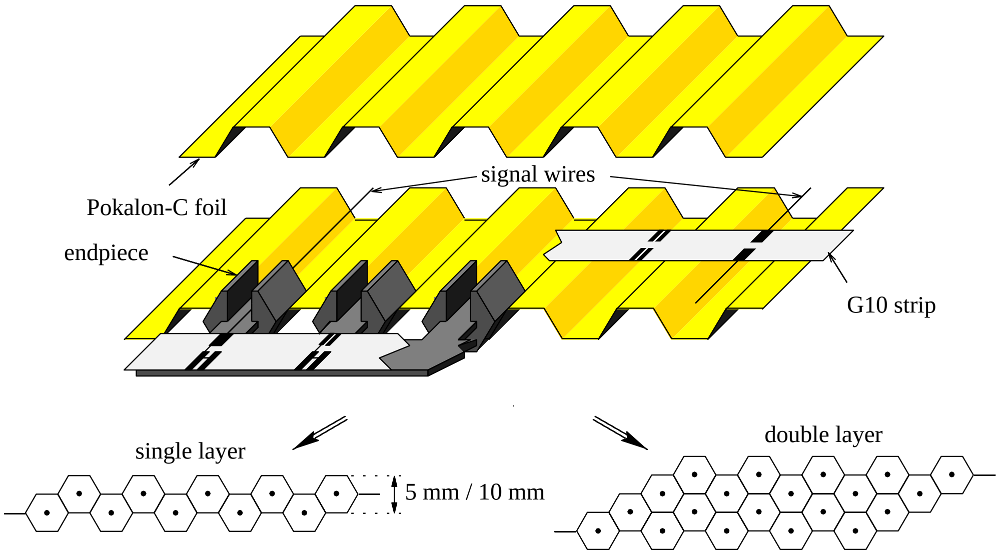


Adopted Solutions for the OTR

Safety

Foil coating R&D

Coat the 12000 foils with
50 nm Cu (good adhesion to plastics)
+ 40 nm Au (gas contact material)



Materials validated up to 1.2 C/cm

- FR4 supporting bridges
- Glues (Stycast and Conductive Glue)
- Wires (W/Au and Cu/Be)
- ULTEM end pieces
- Aluminum in contact with gas
- Possibility to use Rilsan tubing

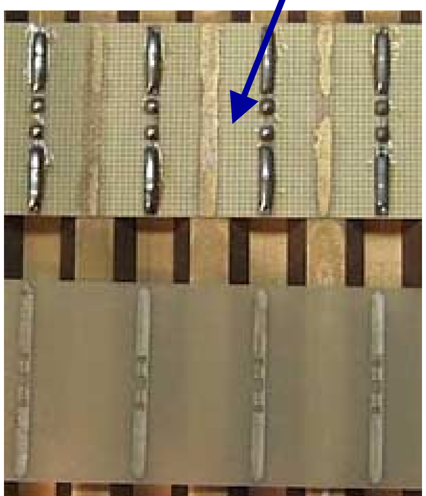
Procedures validated up to 1.2 C/cm

- Soldering points do not need to be cleaned from colophony
- Anti-contact paste in the template can be used (out-gassing proven)
- Gas exchange (with no CH_4 content) of ~ 1 vol/h does not produce aging

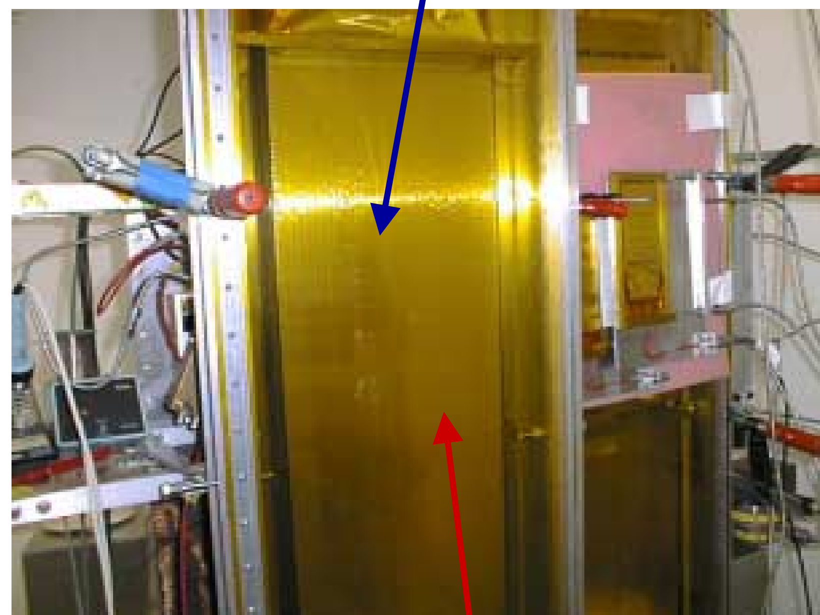
Permanent Dark Currents

- Chambers running at a gas exchange of ~0.1 vol./h show permanent dark currents after ~300 mC/cm of accumulated irradiation charge ($Ar/CF_4/CO_2$).
- A similar effect was already observed after a test in X-rays in Heidelberg.
- Analysis of strips show changes.

Glass fibers are visible

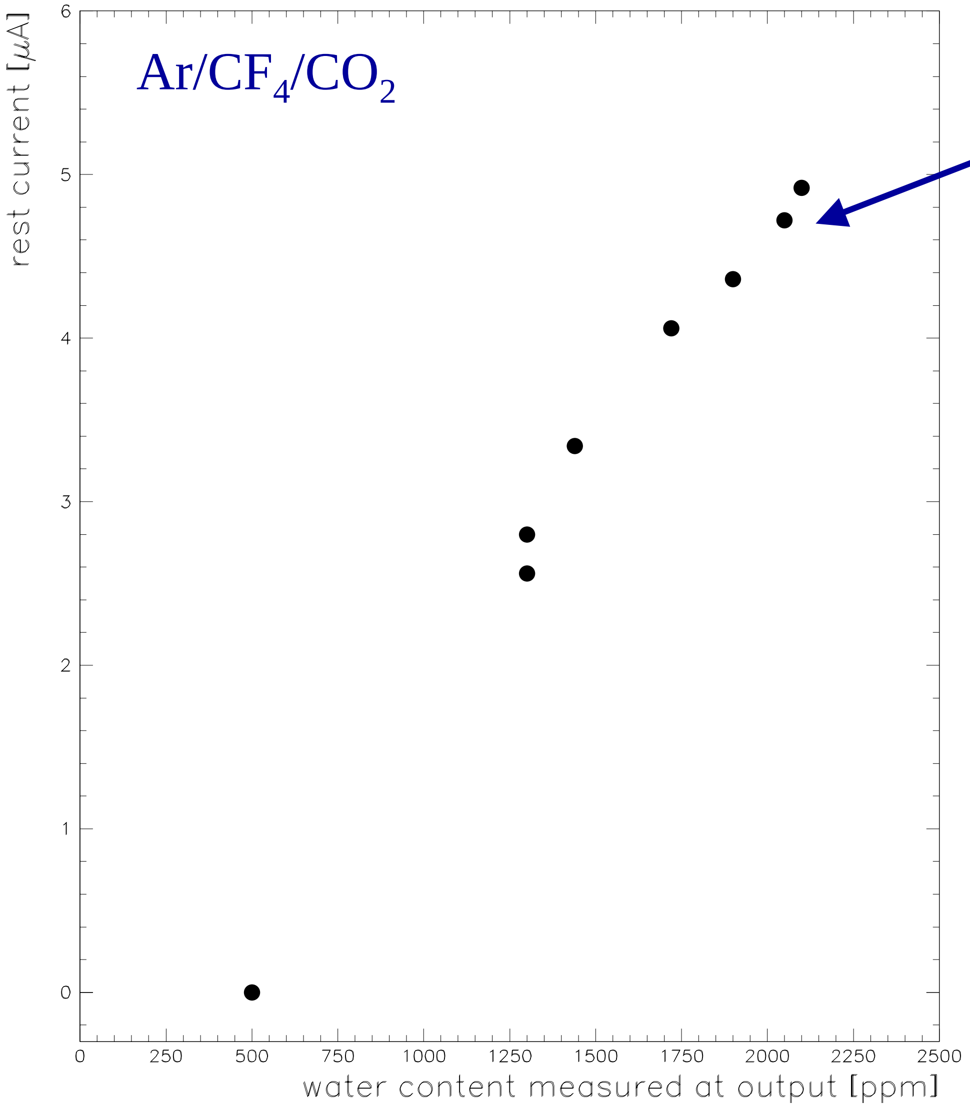


Strips have become conductive



Big Kapton window

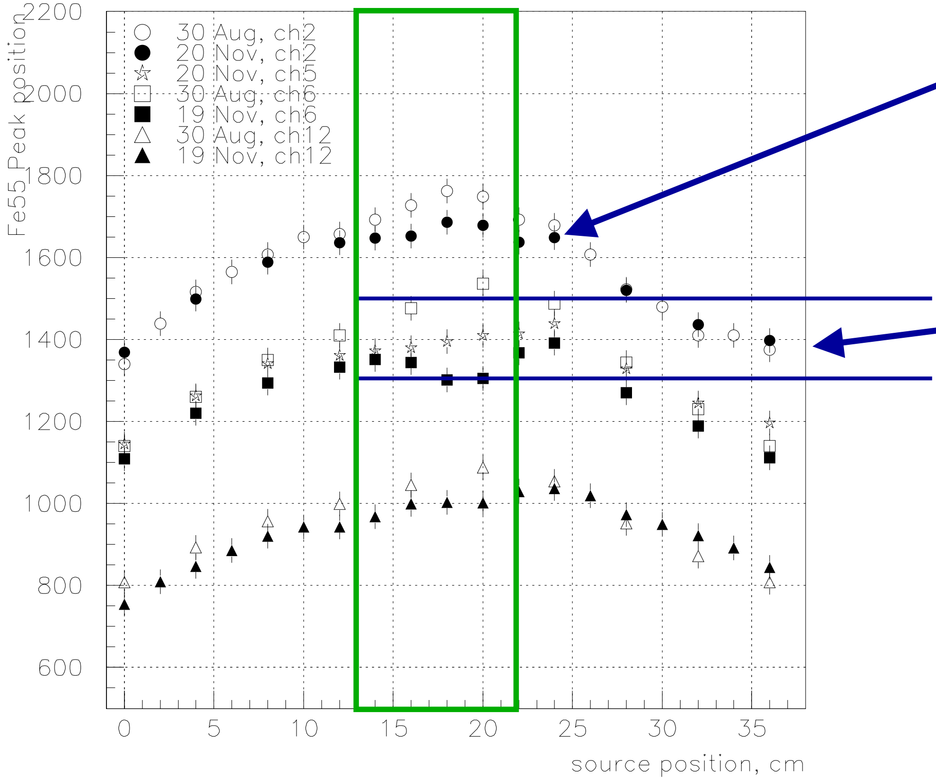
Implications for the Gas System

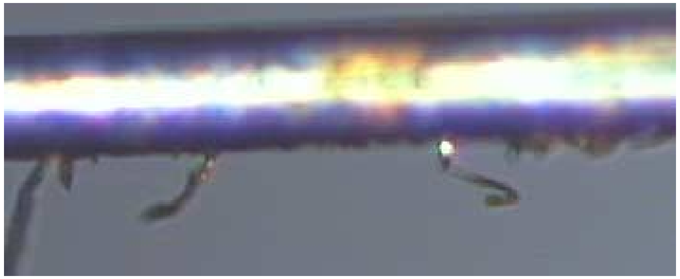


Clear dependence with the water content in the gas

Surface conductivity in the supporting bridges strips can be avoided by carefully controlling the gas water content (< 500 ppm)

Wire Etching: Gas System Constraints





Several tests indicate that the wire etching is present if water concentration is too low (< 100 ppm) or also too high???

(see A.Schreiner and other talks)

Summary and Conclusions (General)

- Aging tests must be done in very "similar" conditions to the place where the detector is going to run.
  - The problem is to realize the parameters that define "similar".
    - Charge density.
    - Irradiation area.
    - Particle type and energy.
    - Space charge vs. accelerated aging.
  - X-rays alone might not be sufficient.
- Materials and building techniques must be carefully scrutinized
  - Use only "allowed" materials and gasses.
  - Carefully check the way detectors are built.
- Attention must be paid to the constraints in the design of the gas system
  - Test of purifiers.
  - Thresholds in impurities.

Summary and Conclusions (HERA-B)

A hadron beam above several MeV of energy resembles some of the key conditions (in terms of aging) of HERA-B

In the HERA-B OTR materials and detector building techniques have been tested up to 1.2 C/cm (~2.5 running years)

The HERA-B OTR does not show aging effects if the water content in the gas is maintained between tight margins (100 –500 ppm), something non-trivial in a huge gas system (with re-circulating purified gas at a flow of with 20 m^3/h)

TEST, TEST, TEST ….

….but with very careful parameter control and thinking